MOISTURE ABSORPTION BY PLANTS FROM AN ATMOSPHERE OF HIGH HUMIDITY

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(WITH THREE FIGURES)

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The physics of water movement in the soil has been the subject of a great deal of investigation. The role of the plant in soil moisture and soil moisture-plant relationships has been studied less intensively. Under arid and semi-arid conditions plants are often subjected to tensions extending over a wide range of soil moisture percentages, and there is evidence that the plants themselves often contribute to their own survival under moisture stress by absorption and exudation of moisture.

BREAZEALE (**1**), and BREAZEALE and CRIDER (**2**) have shown that a plant can absorb water and transport it from one zone of low tension to one of high tension if a part of its root system is present in both zones. BREAZEALE and McGEORGE (**3**) have shown that this phenomenon can be used to determine the wilting percentage of the soil—that is, the equilibrium occurring when the water-retaining forces of the soil equal the water-absorbing forces of the plant roots.

In the semi-arid southwest summer crops exhibit a distinctly different growth response to rain, which is accompanied by a high humidity, than they do to an irrigation which is accompanied by a low humidity. Winter crops which are grown under more favorable atmospheric conditions with respect to humidity and temperature show less moisture stress than summer-grown crops. It is of interest, in this connection, that along the coast of California, where fogs exist, some crops are grown without irrigation and with only a few inches of rainfall.

The observations of BRIERLEY (**4**) are of interest in this connection. He noted an increase in size of raspberries following a very light shower during which only enough rain had fallen to wet the leaves. The soil was not wetted. He postulated that the increase in size of berries, following such a light shower, might be due to absorption of water by the leaves. In order to study this further, he selected leaves from a large number of different plants and allowed them to wilt after sealing the stem with paraffin. When these wilted leaves were immersed in water they recovered turgidity.

While it is recognized that a low transpiration rate reduces the moisture stress, the question of water intake through the leaves is pertinent. The following experiments were conducted to study water intake through leaves when the above-ground part of the plant is subjected to fog or highly humid atmospheres.

EXPERIMENT 1

Three soil types were selected (light, medium, and heavy) and planted with young tomato plants in glass jars as shown in figure 1. The moisture percentage in the soils was kept at field capacity for one month in order that the plants might become well established and develop a large root system. At this point the surface of the jar was sealed off with a paraffin-beeswax mixture and the plants allowed to continue growing until they had reached the wilting point. The plants from two jars of each soil type were removed

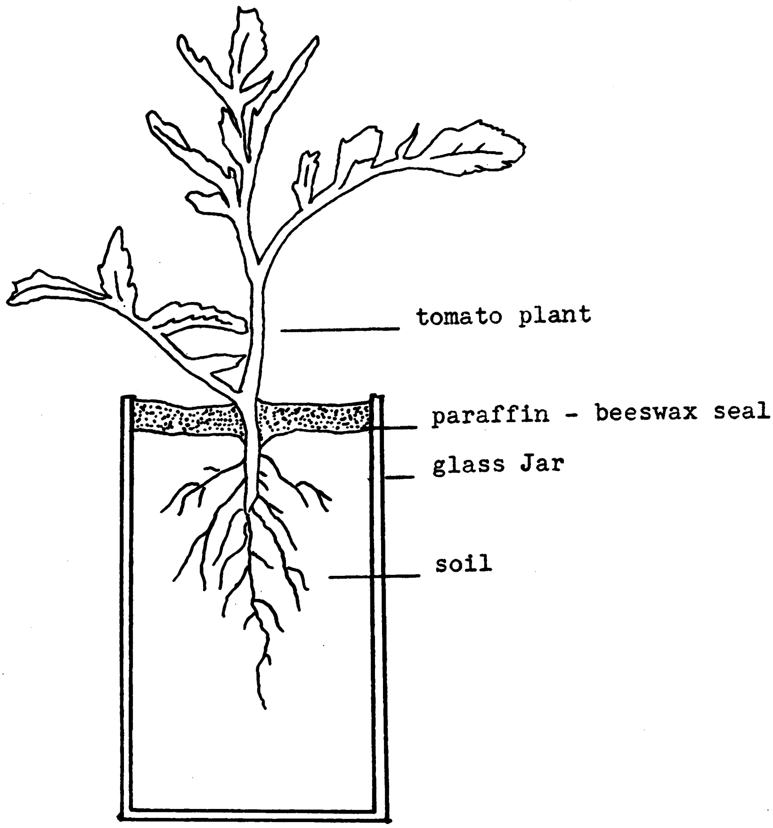

FIG. 1. Method of growing plants in jars of soil protected by a surface seal of paraffin-beeswax mixture.

and the moisture percentage of the soils determined. These data are given in column 2 of table I. At the same time two jars of each soil type, containing wilted plants, were transferred to a saturated atmosphere. Saturation was maintained by using a "fogger" of the type used on vegetable display tables. Two plants of each soil type were removed from the saturated atmosphere at the end of 24 hours and two after 48 hours. The paraffin-beeswax seal and plants were removed and moisture percentage determined in the soil. These data are given in columns 3 and 4 of table I.

The data show a rapid build-up of moisture in the dry soil. This moisture was absorbed by the leaves, transported to the roots, and exuded into the soil. Assuming that field capacity is approximately twice the wilting percentage, the data show that sufficient water was transported through the plants from the foliage to build the soil moisture above the field capacity.

EXPERIMENT 2

A similar and confirming experiment was conducted in which eight-week-old tomato plants were transplanted to percolators filled with soil. Sufficient water was added to bring the soil to field capacity and the top of the percolator then sealed off with paraffin-beeswax mixture. The outlet at the bottom of the percolator was left open. These plant cultures were then placed in a fog as in Experiment 1 where they were kept continuously for 12 weeks. In this period of time the plants flowered and set a crop of tomatoes with no other sources of water than that taken up from the fog.

TABLE I

MOISTURE EQUIVALENT OF LIGHT, MEDIUM, AND HEAVY SOILS; WILTING PERCENTAGE FOR TOMATO PLANTS; BUILD-UP OF MOISTURE IN THE SOILS THROUGH THE LEAVES

SOIL	M. E. OF SOILS	PER CENT. MOISTURE AT WILTING	PER CENT. MOISTURE IN SOILS	
			24 HOURS	48 HOURS
Light	12.5	6.5	18.5	20.2
Medium	22.7	11.9	25.0	27.0
Heavy	36.8	20.0	39.5	47.2

EXPERIMENT 3

In the next experiment moisture absorption through the leaves was studied by a slightly different technic. A series of young tomato plants was sealed in dry, empty 250 ml. Erlenmeyer flasks with glass collars fitted on the stem above the flask as shown in figure 2. The stem was sealed into the cork stopper with paraffin-beeswax mixture. The glass collar was sealed to the cork. The joint between the flask, cork, and collar was then securely taped with rubber tape, thereby forming a water-tight seal. The collar was then filled with air dry soil, a cork was fitted in the top of the collar and sealed securely to prevent entrance of moisture. The plants were then placed in the atmosphere of fog.

After two days the soil in the glass collars was moist and the plants had exuded a small amount of water into the flask. Two weeks later roots were visible in the soil in the glass collar and considerable free water had been exuded into the flasks. At the end of one month the experiment was discontinued and the percentage moisture in the soil from the collar was determined and the volume of water in the flasks measured. The data obtained from two representative plants are given in table II.

The experiment was repeated with the exception that the Erlenmeyer flask was half filled with tap water. The results were the same—the soil in the collars became saturated and the water volume increased in the flask.

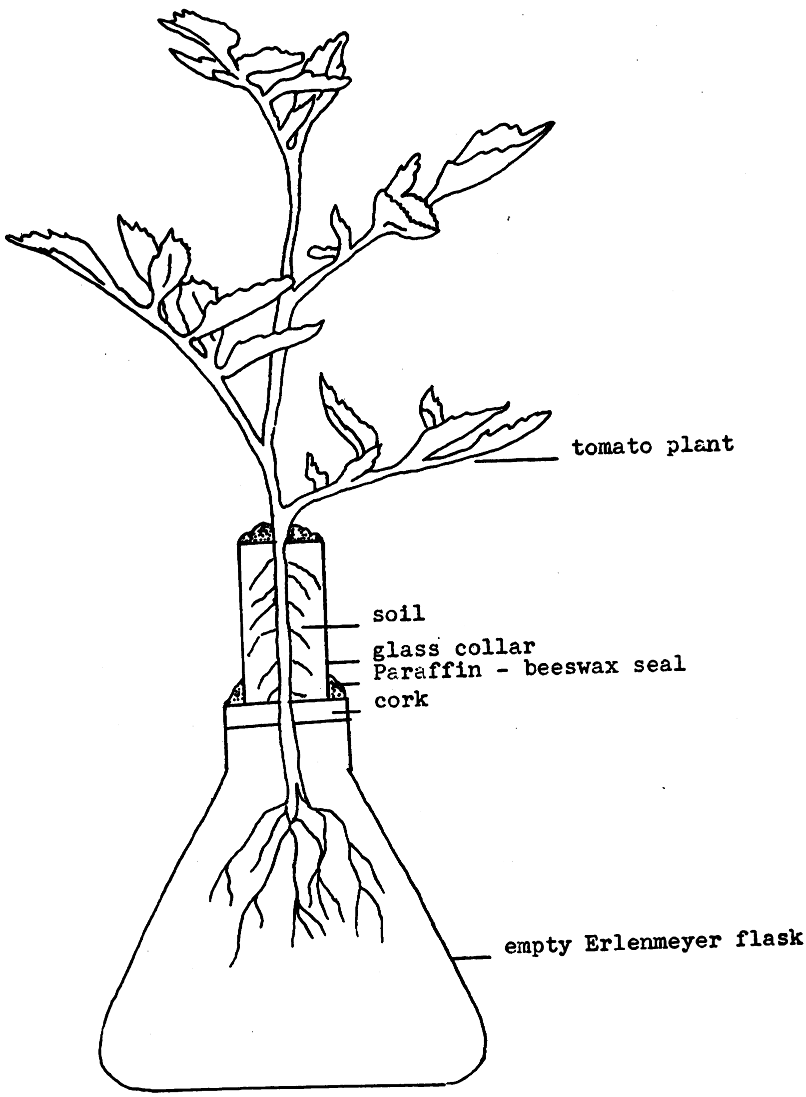

FIG. 2. Method of growing tomato plants with roots in an empty flask with stem collared in soil.

The experiment was repeated several times using soils of different texture in the glass collar. In every case there was a build-up of moisture in the collar to field capacity or higher and free water was exuded into the flasks.

In order to check the security of the paraffin-beeswax seal an experiment was conducted in which the plants were grown in an inverted position. The build-up of water in the soil in the collar and of free water in the empty flask took place at about the same rate as when the plants were grown in an upright position.

TABLE II

TRANSPORT OF ABSORBED MOISTURE FROM LEAVES TO SOIL AND TO EMPTY FLASK

PLANT NO.	ML. WATER IN FLASK	PER CENT. MOISTURE IN SOIL	M. E. OF SOIL	WILTING PERCENTAGE* OF SOIL
1	160	30.1	16.7	9.1
2	185	35.2	16.7	9.1

* CALCULATED FROM MOISTURE EQUIVALENT (M. E.)

At no time during this experiment did the plants show any evidence of a nutritional disturbance indicating that they obtained sufficient nutrients from the soil in the glass collar. Therefore the plant obtained nutrients from the soil even though the soil withdrew water from the plant. The analysis of the free water which had exuded into the flasks indicates that there was a movement of ions from the roots to the moisture film on the root surface.

EXPERIMENT 4

In the last experiment 24 tomato plants were grown in the complete absence of soil—that is, they were sealed in empty 250 ml Erlenmeyer flasks as shown in figure 3. These plants were placed in an atmosphere of fog, as for the previous experiments. Four plants were taken down each week thereafter and the volume of water that had been exuded through the plant into the flasks was measured. These data are given in table IV.

A second series in this experiment was grown under a canopy of cloth in an atmosphere of 100% relative humidity, but one in which a mist of free water did not come in contact with the leaves as in the previous experiments. Here again two plants were taken down each week and the volume of accumulated water in the flasks was measured. These data are given in the last column of table IV.

TABLE III

ANALYSIS OF WATER EXUDED INTO EMPTY FLASK BY TOMATO PLANTS, PARTS PER MILLION

Calcium (Ca)	50	Phosphate (PO_4)	28
Magnesium (Mg)	trace	Nitrate (N)	27
Sodium (Na)	11	Ammonia (NH_4)	none
		Chlorine (Cl)	5

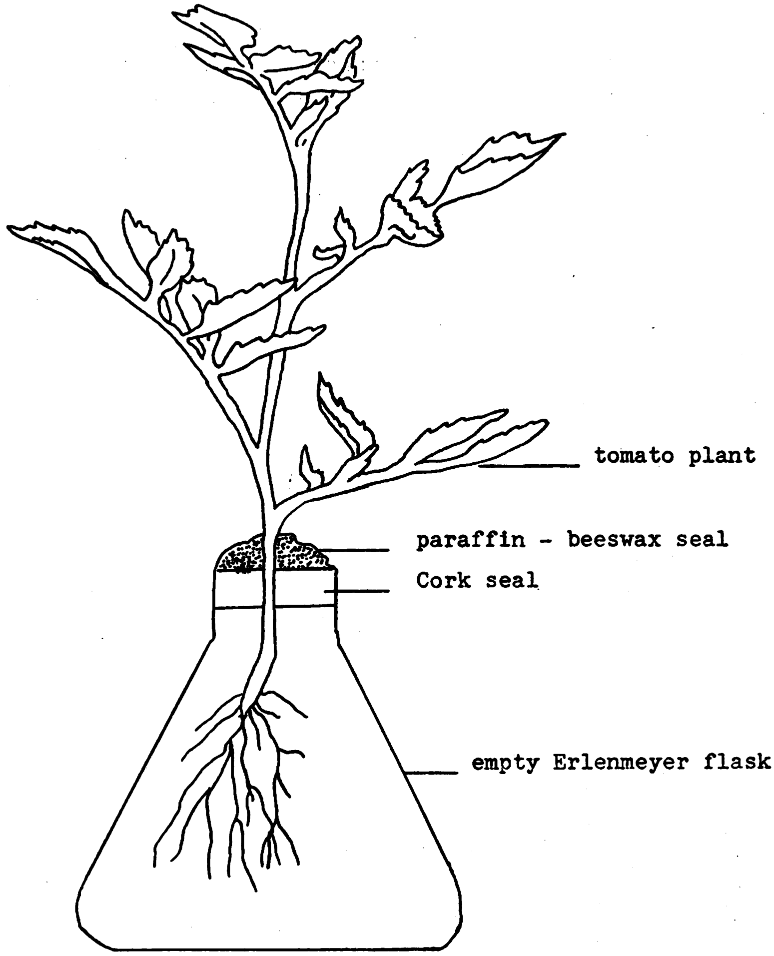

FIG. 3. Method of growing plants in complete absence of soil.

Summary

Under natural conditions the root is the principal water-absorbing organ of plants. These experiments show that when a plant is placed in a saturated atmosphere or fog the leaves become a primary water-absorbing organ. The experiments presented show that in a saturated atmosphere the pressure developed by the absorption of water through the leaves is greater than when water is absorbed through the roots. When a dry soil is "collared" around the stem of a tomato plant growing in a well watered soil the moisture content is built up to the wilting point only (**3**). In Experiment 3 it is shown that when dry soil is "collared" around the stem of a tomato plant absorbing water through the leaves, from a saturated atmosphere, the build-up of water reaches field capacity or higher.

It was shown in Experiments 3 and 4 that the water absorbed by the plant and exuded by the roots is a considerable quantity. In the exuded water nutrient ions pass out of the roots. It is shown that in a dry soil there may be a withdrawal of water from the roots and of nutrient ions from the soil in an atmosphere of high humidity.

A tomato plant can absorb water from a saturated atmosphere, transport it to the roots, and build up the soil moisture to or above the field capacity.

The absorption is greater and the rate more rapid from a fog which maintains an abundance of free water on the surface of the leaves than from an atmosphere of 100% humidity.

TABLE IV

TRANSPORT OF WATER THROUGH THE LEAVES TO THE FLASK

TIME, WEEKS	VOL. ACCUMULATED WATER, ML.	
	FROM MIST	UNDER CANOPY
1	21.7	8.5
2	50.5	17.2
3	83.3	26.5
4	125.2	....
5	145.0	....
6	163.0	....

Tomato plants will grow to maturity, flower, and set fruit with no other source of water than that absorbed through the leaves from a fog or an atmosphere of 100% humidity.

The flow of water in tomato plants is reversible under saturated atmospheric conditions.

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